

THAT WHICH IS CLAIMED IS:

1. A method of flowably dispensing dry powders from a hopper having a dispensing port and a dry powder flow path, comprising:
generating a first non-linear vibration input signal, the first non-linear input
5 signal comprising a plurality of different selected frequencies that correspond a first dry powder formulation;
applying the first non-linear vibration input signal to a dispensing hopper having at least one dispensing port while the first dry powder formulation is flowing therethrough; and
10 dispensing a first meted quantity of the first dry powder through the dispensing port to a receiving member.
2. A method according to Claim 1, wherein the selected frequencies of the non-linear signal correspond to known and/or predetermined flow characteristic
15 frequencies of the first dry powder, and wherein the generating step is carried out to cause the dry powder to flow in a substantially uniform fluidic manner without aggregation.
3. A method according to Claim 2, wherein the dispensing step is carried
20 out by synchronizing the dispensing port to open for a predetermined amount of time, the time corresponding to the dry powder flow rate and amount of meted dry powder desired.
4. A method according to Claim 1, wherein the first meted quantity is a
25 single unit dose amount that is less than about 15mg.
5. A method according to Claim 1, wherein the first meted quantity is a single unit dose amount that is between about 10 μ g-10mg.
- 30 6. A method according to Claim 1, wherein the dispensing step is carried out to successively dispense a plurality of meted quantities, the plurality of meted quantities being between about 10 μ g-10mg, and wherein each of the plurality of

meted quantities are in substantially the same amount with a variation dose to dose of less than about 10%.

7. A method according to Claim 6, wherein the dose to dose variation is
5 less than about 5%.

8. A method according to Claim 1, wherein the non-linear input signal has a plurality of superpositioned modulating frequencies.

10 9. A method according to Claim 1, wherein the dry powder formulation is a low-density dry powder formulation.

10. A method according to Claim 1, wherein the input signal is derived from an evaluation of observed frequencies of time between avalanches as detected in
15 a mass flow analysis of the dry powder formulation.

11. A method according to Claim 10, wherein the derivation of the input signal converts time to frequency space to render frequency distribution data of the mass flow analysis of the dry powder formulation.

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12. A method according to Claim 1, further comprising generating a second non-linear vibration input signal, the second non-linear input signal comprising a plurality of different selected signal frequencies that correspond to predetermined flow characteristics of a second dry powder formulation;

25 adjusting the non-linear input signal to apply a second non-linear vibration input signal to the dispensing hopper while the second dry powder formulation is flowing therethrough, the second input signal being different from the first input signal; and

dispensing a first meted quantity of the second dry powder through the
30 dispensing port to a receiving member.

13. A method according to Claim 1, wherein the applying step is carried out at a localized portion of the hopper.

14. A method according to Claim 1, wherein the applying step is carried out by applying the non-linear vibration energy along a major portion of the length of the hopper, the length of the hopper extending in the direction of flow.

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15. A method according to Claim 12, wherein the non-linear input signal comprises a plurality of superimposed frequencies that are selected to represent a desired number of the most observed frequencies in a flow analysis frequency distribution.

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16. A method according to Claim 1, wherein the applying step is carried out to concurrently apply vibrational energy at multiple selected frequencies.

17. A method according to Claim 1, further comprising increasing the apparent bulk density of the first dry powder during the dispensing step without evacuating the flow path.

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18. A method according to Claim 17, wherein the hopper and dispensing port define a dry powder flow path, and wherein the increasing the apparent density step comprises directing a gas at a first pressure to enter, flow across, and exit the flow path at a second lesser pressure, proximate the dispensing port as the dry powder moves downwardly in the hopper during the dispensing step.

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19. A method according to Claim 1, wherein the hopper has an associated axis extending along the gas flow path, said method further comprising moving the hopper in a centrifugal motion so that it oscillates relative to the axis and generates a force with downward component or vector that is transmitted to the first dry powder formulation during the dispensing step.

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20. A method according to Claim 1, wherein the hopper has an associated axis extending along the gas flow path, said method further comprising moving the hopper in an eccentric motion so that it oscillates relative to the axial center line and

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generates a force with downward component or vector that is transmitted to the first dry powder formulation during the dispensing step.

21. A method according to Claim 1, wherein the non-linear input signal
5 comprises frequencies in the range of between about 10Hz to 1000kHz.

22. A method according to Claim 1, wherein the non-linear input signal
comprises carrier frequencies in the range of between about 15kHz to 50kHz.

10 23. A method according to Claim 1, wherein the hopper comprises an
insert configured to reside in the flow path in the hopper such that it downwardly
extends a distance out of the dispensing port, said method further comprising
translating the insert during the dispensing step to accelerate the particles of the dry
powder formulation.

15 24. A method according to Claim 23, wherein the translating step is carried
out to oscillate the insert with a selected motion that has an associated non-constant
period or periods.

20 25. A method according to Claim 1, wherein the vibration energy input
signal is based on electrical stimulation of the hopper.

26. A method according to Claim 1, wherein the vibration energy input
signal is generated by mechanical stimulation of the dry powder.

25 27. A method according to Claim 1, wherein the vibration energy input
signal is generated by electro-mechanical stimulation of the hopper and/or dry
powder.

30 28. A method according to Claim 1, wherein the vibration energy input
signal comprises imparting a high frequency motion onto a selected portion of the
hopper, with the outer bounds of the motion of the hopper being small.

29. A dry powder dispensing system, comprising:
a hopper configured to hold a dry powder therein, the hopper having at least one dispensing port and a wall with an inner surface and outer surface;
a quantity of a dry powder disposed in the hopper;
5 at least one vibration energy generation source operably associated with the hopper, wherein, in operation, the at least one vibration energy generation source is configured to output a desired non-linear vibratory energy sufficient to impart an angular velocity with downward force vectors to the dry powder as the dry powder flows downwardly to the dispensing port; and
10 a control module operably associated with the hopper and the vibration energy generation source, the control module comprising:
computer readable program code configured to direct the vibration energy source to output the vibration energy corresponding to the dry powder in the system.
- 15 30. A system according to Claim 29, the control module further comprising:
computer readable program code configured to select the output of the vibration energy generation source from a library of non-linear energy outputs
20 associated with a plurality of different dry powders, based on a desired predetermined dry powder specific vibration energy output associated with the dry powder being dispensed.
- 25 31. A system according to Claim 30, wherein the system is configured to dispense a plurality of different dry powders separately, and wherein the control module comprises computer readable program code that accepts user input to identify the dry powder being dispensed, and computer program code that automatically selectively adjusts the output of the vibration energy generation source based on the identified dry powder being dispensed.
- 30 32. A system according to Claim 29, wherein the computer program code for the predetermined dry powder-specific vibration energy output for the dry powder

being dispensed defines an output signal that is derived from flow data experimentally obtained from a flow analysis of the dry powder in the system.

33. A system according to Claim 30, wherein the computer program code
5 for the library of predetermined dry powder-specific vibration energy outputs for the dry powders are derived from data obtained from a mass flow analysis of the dry powders.

34. A system according to Claim 29, wherein the dry powder is a low-
10 density dry powder, and wherein the system is configured to serially dispense a plurality of single unit doses in amounts less than about 15mg.

35. A system according to Claim 34, wherein the single dose amount is
15 between about 10µg-10mg.

36. A system according to Claim 29, wherein the system is configured to
dispense a plurality of meted quantities, the plurality of meted quantities being
between about 10µg-10mg, and wherein each of the plurality of meted quantities are
in substantially the same amount with a variation, dose to dose, of less than about
20 10%.

37. A system according to Claim 30, wherein the computer program code
of predetermined vibration generation source output signals is derived from selected
parameters of a mass flow analysis of the dry powders.

25 38. A system according to Claim 37, wherein the derivation converts time space data of the mass flow analysis of the dry powders to frequency space data.

39. A system according to Claim 29, wherein, in operation, the vibration
30 energy generation source is configured to deliver the output signal and cause the dry powder to flow in a substantially uniform fluidic manner without aggregation.

40. A system according to Claim 29, further comprising a valve operably associated with the at least one dispensing port and in communication with the control module, the valve being configured to open and close the flow path across the dispensing port to controllably dispense metered quantities of dry powder by permitting
5 flow of the dry powder out of the dispensing port for a predetermined time at a substantially uniform flow rate, the flow rate and open time of the valve during the valve operation cycle corresponding to the desired dispensed dose amount.

41. A system according to Claim 29, wherein the vibration generation
10 source is configured to output high frequency vibration energy.

42. A system according to Claim 29, wherein the hopper comprises a piezoelectric material that is operably associated with the dry powder in the hopper, and wherein the vibration energy generation source comprises a power source that can
15 supply a selected electrical input signal to the piezoelectric material, wherein, in operation, the piezoelectric material outputs the desired vibration energy to the dry powder.

43. A system according to Claim 29, wherein the vibration generation
20 source is configured to increase the apparent bulk density of the dry powder in the hopper during dispensing in the absence of evacuation.

44. A system according to Claim 43, further comprising:
a permeable member attached to the hopper and positioned proximately above
25 the dispensing port and defining a portion of the dry powder flow path; and
a forced gas source configured to direct gas to enter a first side of the permeable member at a first pressure, flow across the gas flow path, and exit the permeable member at a different location at a second pressure to generate a pressure differential across the width of the gas flow path proximate the permeable member.

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45. A system according to Claim 44, wherein the permeable member is a stainless steel filter or frit.

46. A system according to Claim 44, wherein the hopper, the permeable member, and the dispensing port define an axially extending dry powder flow path, and wherein, in operation, the apparent bulk density of the dry powder is increased as the dry powder moves downwardly in the hopper due at least in part to the
5 transversely generated pressure differential.

47. A system according to Claim 29, wherein the hopper and associated dispensing port have an associated axis extending along the gas flow path, said system further comprising a translation mechanism that moves at least a portion of the hopper
10 in a centrifugal motion so that the hopper and/or dispensing port oscillates relative to the axis and, in operation, generates a force with a downward component or vector that is transmitted to the first dry powder during dispensing.

48. A system according to Claim 29, wherein the hopper and dispensing
15 port have an associated axis extending along the gas flow path, said system further comprising a translation mechanism that moves at least a portion of the hopper in an eccentric motion so that at least a portion of the hopper oscillates relative to the axis and, in operation, generates a force with a downward component or vector that is transmitted to the dry powder during dispensing.

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49. A system according to Claim 29, wherein the vibration energy generation source outputs a non-linear input signal comprising vibration excitation frequencies in the range of between about 10 Hz to 1000 kHz.

25 50. A system according to Claim 29, wherein the vibration energy generation source outputs a non-linear input signal comprising at least one carrier frequency in the range of between about 15kHz to 50kHz and a plurality of modulation frequencies in the range of between about 10-500Hz.

30 51. A system according to Claim 29, further comprising an elongated insert configured to reside in the flow path in the hopper such that the insert downwardly extends a distance out of the dispensing port and eccentrically rotates

relative to the axis of the flow path of the hopper during dispensing to transmit directional acceleration to particles of the dry powder.

52. A system according to Claim 51, wherein, in operation, the insert is
5 oscillated with a selected motion that has an associated non-constant period.

53. A system according to Claim 29, wherein the vibration generation energy output comprises a high frequency motion applied onto a selected portion of the hopper, with the outer bounds of the motion of the hopper being small.

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54. A system according to Claim 29, further comprising a computer program product controlling the dispensing of dry powders, the computer program product configured to control the activation of a valve that opens and closes the flow path of the dispensing system to control the amount of dry powder dispensed in unit
15 dose amounts of less than about 15mg.

55. A computer program product for operating a flowing dry powder processing and/or dispensing system having an associated dry powder flow path with a dispensing port and a vibration energy source associated therewith to facilitate
20 fluidic flow, the computer program product comprising:

a computer readable storage medium having computer readable program code embodied in said medium, said computer-readable program code comprising:

computer readable program code that identifies a plurality of powder-specific vibration energy signals, each corresponding to an individual flow analysis; and

25 computer readable program code that directs the dispensing system to operate using the powder-specific vibration energy signal associated with a target dry powder.

56. A computer program product according to Claim 55, wherein the powder specific vibration energy signals are non-linear.

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57. A computer program product according to Claim 55, further comprising computer program code that accepts user input to identify the dry powder being dispensed, and computer program code that automatically selectively adjusts

the output of the vibration energy signal based on the identified dry powder being dispensed.

58. A computer program product according to Claim 55, wherein the
5 vibration energy output signals for the dry powders being dispensed are based on data obtained from a flow analysis of different dry powders.

59. A computer program product according to Claim 55, wherein the
dispensing system is configured to dispense low-density dry powder.
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60. A computer program product according to Claim 55, further
comprising computer program code that controllably dispenses meted quantities of
dry powder independent of volumetric evaluations by considering flow rate of the dry
powder out of the dispensing port and controlling the amount of time the dispensing
15 port is open during dispensing.

61. A computer program product according to Claim 60, and wherein the
computer program product is configured to controllably dispense a plurality of single
unit doses of low density dry powders in amounts less than about 15mg.
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62. A computer program product according to Claim 61, wherein the
single dose amount is between about 10 μ g-10mg.

63. A computer program product according to Claim 62, wherein the
25 computer program product is configured to controllably dispense a plurality of meted
quantities of low-density dry powder, the plurality of meted quantities being between
about 10 μ g-10mg, and wherein each of the plurality of meted quantities are in
substantially the same amount with a variation, dose to dose, of less than about 10%.

64. A computer program product according to Claim 55, further
30 comprising computer program code that automatically repeatedly actuates a valve
operably associated with the dispensing port to open and close the dispensing port
according to the desired meted quantities and filling protocol.

65. A method of measuring doses of dry powder formulations, comprising:
tensioning an elastomeric piezoelectric material with metallic conductive
portions thereon;
5 dispensing a quantity of a dry powder onto the piezoelectric material about a
predetermined location proximate at least one of the metallic conductive portions, the
dispensing causing the flexing of the piezoelectric material;
measuring an alteration in a selected electrical parameter associated with the
flexure of the piezoelectric material; and
10 determining the mass of the dispensed dry powder based on the measured
alteration.

66. A method according to Claim 65, wherein the piezoelectric material is
PVDF, and wherein the step of measuring is carried out by sensing the voltage
15 generated by the piezoelectric film responsive to the weight of the dry powder
positioned thereon.

67. A method according to Claim 65, wherein the step of measuring is
carried out by sensing a change in capacitance generated by the piezoelectric material
20 due to the applied force associated with the weight of the dry powder positioned
thereon.

68. A method according to Claim 65, wherein the step of measuring is
carried out by sensing a change in the resonant frequency in the piezoelectric material
25 due to the applied force associated with the weight of the dry powder positioned
thereon.

69. A method according to Claim 65, wherein the dispensing is carried out
for single dose amounts about 30mg or less.
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70. A method according to Claim 65, wherein the dispensing is carried out
for single dose amounts between about 10 μ g-10mg.

71. A method according to Claim 65, wherein the dry powder is a low density dry powder.

72. A system for measuring doses of dry powder formulations, comprising:
5 means for tensioning an elastomeric piezoelectric material with metallic conductive portions thereon;

means for dispensing a quantity of a dry powder onto the piezoelectric material about a predetermined location proximate at least one of the metallic conductive portions to cause the flexing of the tensioned piezoelectric material by
10 dispensing the dry powder thereon during the dispensing;

means for measuring an alteration in a selected electrical parameter associated with the flexure of the piezoelectric material; and

means for determining the mass of the dispensed dry powder based on the measured alteration.

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73. A system of flowably dispensing dry powders from a hopper having a dispensing port and a dry powder flow path, comprising:

means for generating a first non-linear vibration input signal, the first non-linear input signal comprising a plurality of different selected frequencies that
20 correspond to a flow analysis of a first dry powder formulation;

means for applying the first non-linear vibration input signal to a dispensing hopper having at least one dispensing port while the first dry powder formulation is flowing therethrough; and

means for dispensing a first meted quantity of the first dry powder to a
25 receiving member.